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THE AMERICAN

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VOL. VII. ANN ARBOR, DECEMBER, 1890. No. 8.

ORIGINAL ARTICLES.

THE THUNDER-STORMS AND WATER-SPOUT AT NEW HAVEN, CONN., ON OCTOBER 19, 1890.

BY H. J. COX.

The weather at New Haven, Conn., on Sunday, October 19th, seems to be of more than passing interest, and it is the intention of the writer in this article to treat with the conditions which attended these peculiar phenomena. The morning Signal Service weather map of Saturday, the 18th, showed that there was a well-defined storm center near Chicago, where the barometer read 29.76 inches, although two stations only within the area of low pressure reported precipitation during the preceding twelve hours, and strangely enough these two stations, St. Paul and Duluth, were in the northwest quadrant and reported rainy weather at the time of observation. At the same time an area of high barometer covered the South Atlantic states, with the highest reading 30.24 inches at Augusta, Ga. There was another storm center on the coast of Nova Scotia, which had moved northeastward from Connecticut during the 17th, causing heavy rains throughout New England.

At 8 A. M. October 18th, between the two cyclones referred to, there was a projection northward to the Lower Lakes from the South Atlantic anti-cyclone. The northern extremity of this projection or ridge was Buffalo, where the barometer read 30.02 inches. The sky at New Haven was absolutely free from clouds during the entire day and until after midnight of the

18th. The barometer fell slowly from 30.00 inches at 8 A. M. to 29.90 inches at 8 P. M. The wind which was fresh westerly died away at sunset, the calm continuing until midnight. Weather maps were not issued at 8 P. M. on the 18th or at 8 A. M. on the 19th, but telegrams from the Chief Signal Officer stated that the western cyclone was moving eastward and was central over Lake Erie on Saturday night, on the New Jersey coast Sunday morning, and near Long Island at 3 P. M. the same day. The weather map at 8 P. M. Sunday showed the center to be near Block Island, the barometer reading 29.32 inches.

A very light wind sprung up from the southwest at New Haven at midnight of the 18th. It slowly backed to SE and E, but did not become fresh until 4:30 A. M. of Sunday, the 19th. The writer has the information from a reliable source that the sky remained absolutely cloudless until 2:30 A. M. Sunday, and after that time the cirrus clouds gathered rapidly. At daybreak the sky was overcast with stratus clouds moving rapidly from the east.

At 8 A. M. the barometer read 29.67, having fallen .23 inches in the past twelve hours. It did not begin raining until 9 A. M., and this was during the passage of a thunder-storm from the west.

The fact that there was no local sign, in the shape of cirrus clouds, of the approach of this cyclone until the early morning of the 19th, furnishes conclusive evidence of the controlling influence which a ridge of high barometer exerts, no matter how slight that ridge may be. When no area of high barometer intervenes it is of constant occurrence that the cirri show the coming of the cyclone, whose center has not yet reached the Mississippi river. Yet the cyclone in question had reached the central part of Pennsylvania before a cloud was seen on the sky at New Haven.

It is remarkable that although the storm center had reached the New Jersey coast at 8 A. M. Sunday, rain did not begin falling until an hour later at New Haven, and then in the form of a thunder-storm. However, the delay in the coming of the rain was probably due to the fact that the atmosphere was comparatively free from moisture, as heavy rain (1.16 inches) had fallen during a storm on the 17th, two days previous, and because the wind did not back from westerly to the rain direction until the early morning of Sunday. The relative humidity at 8 A. M. at New Haven was 84 per cent. In summer it quite

frequently happens that a cyclone moving down the St. Lawrence valley does not cause rain at New Haven until the center has reached this meridian, and then the rain is invariably in the form of a thunder-storm. But when the movement is similar to that of the one under consideration, rain generally begins to fall long before the center has reached the Jersey coast.

The thunder-storm referred to above continued from 9 A. M. to 11:10 A. M. The wind which was brisk and high easterly before the thunder-storm gradually decreased in force to light. It veered to west during the storm and backed to east at 11 A. M. The rainfall was .62 inches. It apparently cleared at 11:15 A. M. and was pleasant with sunlight until 2:45 P. M. During this time there was about three-tenths cirro-cumulus clouds on the sky moving from the east.

From 2:45 P. M. to 3 P. M. cumulo-stratus clouds formed rapidly in the west and southwest, and moved eastward over the city. At 3:15 P. M. lightning, from a lowering cloud directly overhead, shot downwards with a sharp electric crack and struck two buildings within one hundred and sixty yards of the Signal Office. Immediately the rain came down in torrents, 1.18 inches falling in one hour. The rain ended at 4:55 P. M., and it soon cleared, there being from two-tenths to four-tenths cumulus and cirro-cumulus clouds on the sky until after 10 P. M. The wind which was east before the storm backed to west at 3:25 P. M., and remained at that point during the evening. As stated above a telegram from the Chief Signal Office showed the center of the cyclone to be near Long Island at 3 P. M. At that hour the barometer at New Haven read 29.38.

While the above thunder-storm was prevailing over the city, another storm was visible about five miles southward, at the mouth of New Haven harbor, moving along the sound from E to W, or in an opposite direction to the former. The clouds were very dark and at 3:30 P. M. a funnel-shaped cloud, resembling an immense black balloon, seemed to project downward and rapidly approach the water. The water under the funnel seethed and boiled and rose upward about three feet. After the spout was complete, the water was drawn or forced up over thirty feet, due to the rapid gyration from right to left. The spout was about 300 feet in height and 25 feet in diameter. It moved westward about two miles in ten minutes when it met the thunder-storm moving from the west, and was then moved backward toward the east about one mile. As soon as its direction

was changed, the black aspect of the spout seemed to decrease, and gradually change to a dull gray. It finally broke at one-third of its height and disappeared. The entire duration of the water-spout was fifteen minutes. The barometer at the signal office did not appear to change from 3:00 P. M. to 3:30 P. M., but the pressure must have been two and a half inches less in the center of the spout as the water rose up under it about three feet. The wind was light during the afternoon except from 3:25 to 3:35, when it blew in short gusts with a recorded velocity of sixteen miles per hour. It is remarkable that during these gusts, weak though they were, the oscillation of the barometer, aptly termed "pumping" by Ferrel, was observed.

It is interesting to note that the two conditions which M. Defranc considers essential to the existence of a water-spout obtained on the 19th; first, presence of the sun during or a little before the phenomenon; second, the absence of wind, or only a very feeble one, except in the space occupied by the water-spout. It was reported that another spout was seen at Milford, about ten miles west of New Haven, at 3:30 P. M.

The barometer rose slowly after 4 P. M., reading 29.43 at 8 P. M. Rain began falling again at 11.45 P. M., continuing at intervals until 8 A. M. Tuesday the 21st.

It is peculiar that the only rain that fell on the east side of this cyclone was in the shape of two thunder-storms, after both of which the clouds cleared away, several hours of fair weather following; while the continued cloudy and rainy weather did not begin until the cyclonic center had passed the station and had moved more than one hundred miles eastward.

It is understood that in a cyclone the velocity of the wind increases as the center is approached, except that in the center there is a calm. But on Sunday, the 19th, the wind was light (except for ten minutes) during the twelve hours that the center was nearest New Haven. It is not to be supposed that the center was over the city for so long a time, although there is every reason to believe that the center passed almost directly over, and moved to the east as the afternoon thunder-storm approached. The center seemed to be spread out and the barometric gradient was very small, and this furnishes an explanation of the light wind. The gradient was much greater a considerable distance from the center, and hence the brisk and high winds during the morning of the 19th and the night of the 19th and 20th.

TEMPERATURE IN ANTI-CYCLONES AND CYCLONES.*

BY DR. J. HANN.

At the session of the Imperial Academy of Sciences (Vienna) of April 17, 1890, Dr. Julius Hann presented a treatise under the title, "The Air Pressure Maximum of November, 1889, in Central Europe, together with Remarks upon Barometric Maxima in General." It gave first a description, illustrated by two charts, of the atmospheric conditions in Central Europe, especially in the Alpine region, during the barometric maximum November 12–24, 1889. As this high area remained stationary during the whole time, with the center over the Alps, it was practicable to utilize the observations of the now numerous stations, some as high up as 3,100 meters (10,000 feet), for a thorough examination of the meteorological conditions of the upper atmospheric strata during the prevalence of a high pressure area. It was especially sought to determine approximately the distribution of pressure and temperature at a level of 2,500 meters (8,200 feet), with the help of nine elevated stations in the Alps and the aid of stations on the Pic du Midi (Pyrenees) and Puy de Dôme (Southern France) and on the Schneekoppe (Austro-Prussian frontier). As seven of these stations were at a level above 2,000 meters, the pressure arrangement could be computed with sufficient accuracy. Another table gave all the more important meteorological elements for the period of highest barometric readings, November 19–23, at the lower and higher levels in detail.

The main results of the discussions and conclusions associated with this table may be summed up in the following points:

1. The barometric maximum of November, 1889, extended to a very great height in the atmosphere. The pressure observations show that it was as well defined at an elevation of over 3,000 meters above the sea as on the earth's surface. At an elevation of 2,500 meters, the position of the center corresponded with that on the earth's surface.

2. The body of air in the barometric maximum had a high temperature. Even at a height of more than 3,000 meters, the relative heating was as great as at 1,000 meters, (8° C., or 14.4° F. above the average). The usual cooling of winter anti-

* From the Austrian *Meteorologische Zeitschrift*, of June, 1890. Translated and condensed by J. P. H.

cyclones was confined to the air layers next the earth and of 100 meters' thickness. The mean temperature-excess (over the normal) of the air column up to 3,100 meters, for the interval November 19–23, may be estimated as at least 6° C. (10.8° F.). Even at the lowest estimate the temperature-excess must have reached up to 5,000 meters (16,400 feet).

3. In the upper warm layers, say about 1,000 meters up, great dryness prevailed in the air. The mean relative humidity from November 19 to 23, on the Sonnblick, (3,105 meters), was only 43 per cent.; on the Sentis (2,500 meters), 34 per cent. according to carefully reduced psychrometer observations.

The author saw in these results positive evidence that the air in a high area is embraced in a descending motion, and that the pressure conditions of the same cannot be explained by the temperature condition, but must be a result of the motion-system. The heat conditions are dependent on this motion-system; they are products of the same, as are the dryness of the air, the clearness of the sky, and the unusually increased heat-radiation (in the winter-half of the year) by which the cold of the lowest resting strata is explained.

Another section of the treatise is devoted to an investigation of the vertical temperature-distribution in a low pressure area, in order to make possible a comparison of that with a high area. Opportunity for this was afforded by the barometric minimum of October 1, 1889, which lay fairly central over the Alps. With the aid of numerous stations up to a height of 3,100 meters, the following points were determined:

The mean temperature-departure of the air column from the 30-year average, in a low pressure area up to 3,100 meters above sea-level was —4.3° C. (—7.7° F.). The negative variation was tolerably uniform through the whole elevation. (Sonnblick —3.8° C., or —6.8° F.).

These computed temperatures of the low area of October 1, 1889, and the high of November 19–23, yield the following results, according to observations up to 3,100 meters:

Height, meters.	500	1000	1500	2000	2500	3000	3500
Low	7.9	5.1	2.3	—0.6	—3.4	—6.2	—0.1
High	—2.7	6.3	4.4	2.5	0.6	—1.3	—3.2

The temperature in the high area is given from observations at about 7 A. M.; that for the low area is the daily mean. The comparison is therefore as unfavorable as possible, and yet the air in the high area late in November was warmer than that of

the low on October 1. An approximate mean temperature for an air column of a height of more than 3,100 meters gives: For the low of October 1, 1889, —0.6° C.; for the high of November 19-23, + 1.6°. Later data make this latter value too low. If one estimates the mean temperature from the barometer-readings on the Sonnblick and at Ischl, he finds this to be 2.8° for the interval between 470 and 3,100 meters.

The author shows very fully that during the conspicuous prevalence of southerly winds on October 9-10, which set in as a warm Fœhn in the valleys on the north side of the Alps, the temperature on Sonnblick peak (3,105 meters, or 10,187 feet) was lower than during the prevalence of the high area, November 19-23. On the highest Alpine station only the high area brought the greatest heating. The thermometer always rose with the pressure.

We have to thank the recently established peak-stations for being able to free ourselves from the old idea into which observations at the earth's surface (or in elevated valleys) beguiled us: that the temperature in cyclones and anti-cyclones is a principal cause of the respective motion-systems of the atmosphere. According to the foregoing this much is established: That questions about the causes of the same must deal with the fact that up to a height of 4,000-5,000 meters (13,000-16,000 feet) the mean temperature in the column of an anti-cyclone may be, and probably always is, higher than that in the center of a cyclone.

Therewith fall the formerly prevailing views as to the cause of cyclones, as, for instance, Ferrel enunciates them in his latest work. The observations are, on the other hand, in harmony with the views of those who, like the author, regard the moving cyclones and anti-cyclones as phenomena consequent upon the general circulation, the energy of whose movement, as formerly was the case, is traced back to the temperature-difference between equator and pole. The temperatures in the cyclone and the anti-cyclone are determined by the motion-systems of the air, and not the reverse. With stationary cyclones and anti-cyclones, over the oceans and continents, especially in high latitudes, this principle has only a partial application. The permanent temperature-differences in those places explains an atmospheric circulation of a secondary rank. Teisserenc de Bort therefore distinguishes, it seems to us properly, between dynamic and thermic cyclones and anti-cyclones. Where the descending movement prevails, the temperature rises; where

there is an ascending motion, there it falls. The condensation of water-vapor, setting in in the latter case, can and must lessen the temperature-decrease, but it cannot arrest, much less reverse, this process. Since, then, the temperature-increase in a descending air-mass is more rapid than in an ascending one, the sinking portion of a complete vertical circulation must have a higher temperature than the rising. The facts embodied in the aforesaid treatise are in harmony with this reasoning.

AN ELECTRIC STORM.

By G. E. Curtis.

On April 8, 1890, eastern Colorado was visited by an electric storm of unusual intensity. The accompanying phenomena were these: A low pressure area, central over Iowa, was enclosed by an isobar of 29.5 inches. The pressure increased rapidly westward, reaching 30.3 inches at Eagle Rock. This steep barometric gradient was, of course, accompanied in Colorado by violent northwesterly winds and falling temperature. At 8 A. M., 75th meridian time, the temperature was 40° at Denver, and increased southeastward to 70° at Ft. Smith, Arkansas. The severe gale of wind that was developed under these conditions was accompanied by an unusual display of atmospheric electricity, as described in the following passages from the reports of observers. I believe that the collation of descriptions like these together with the accompanying meteorological conditions will add greatly to our knowledge of the development of atmospheric electricity and of the occurrence of electric storms.

Abbott, Colo.: "April 8th, severe wind-storm accompanied by dust occurred, beginning about daylight and lasting till nearly sundown, unroofing houses and overturning a few of the most frail, and doing considerable damage to out-buildings. A strange feature of the storm was that the air was so full of electricity as to charge a number of stoves in town, also the wire fences. The stoves were so highly charged that anyone attempting to remove a kettle or cooking utensil of any kind would receive a very severe shock. By putting the hand near the stove one could see the flash of the electricity as it went from the stove to the hand."—S. T. Shipman.

Yuma, Colo.: "The most severe gale of wind since February,

1887, passed over this region to-day, April 8th, commencing about 5 A. M. and continuing until nearly sunset, but spending its greatest fury before noon. It was accompanied by much atmospheric electricity, we often receiving shocks from contacts with the stove-lifter or damper or even touching the foot to one of the stove legs. Sparks were also often seen, and the usual crackling sound heard just before said contact."—IRA EDWARDS.

Laird, Colo.: "April 8th, high winds and sand storm."—F. S. CARY.

Sanborn, Colo.: "April 8th, very high northwest wind, blowing from 9 A. M. to 1 P. M."—G. C. SMITH.

Kirk, Colo.: "April 8th, sand blizzard—very high wind from the north."—GEO. M. NEIKIRK.

Sheridan Lake, Colo.: "April 8th, we had a very heavy wind storm and the air seemed to be full of electricity. Wire clothes-lines, stove-pipes, etc., were charged with it . . . . A very heavy wind and electric storm all day."—W. A. RIGOR.

Brandon, Colo.: "April 8th, a very hard wind from the north during the entire day."—J. H. WELLER.

Wray, Colo.: "April 8th, the hardest wind for three years, and plenty of electricity in the air; wind was from northwest." —J. W. DILTO.

OBSERVATIONS AND STUDIES ON MT. WASHINGTON.

BY PROFESSOR H. A. HAZEN.

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A station for meteorological observations has been established for more than nineteen years at this point, and during most of this period there has been a continuous record from three to seven times each day of all the elements usually observed. Mt. Washington is most opportunely situated as a station of research of upper atmospheric phenomena, since a large proportion of the storms which pass over the northern United States have a track nearly over the summit, and many of the areas of high pressure also take the same direction. The Chief Signal Officer in July of 1889 decided to have a few special observations made in addition to the usual routine, and the following report is made of work during six weeks in July and August, 1889.

Mt. Washington is almost an isolated peak rising to the height of 6,300 feet. It is nearly in the center of the Presiden-

tial range which has a general direction from SSW to NNE for about nine miles. On the east, north and south sides of the range there are deep valleys and the country is very much broken up by other and lower ranges of hills. On the west, however, the Ammonoosuc valley is almost uninterrupted from the base to a distance of twenty miles. This valley has an important bearing upon the meteorology of the mountain, since a large proportion of the winds come from the west right up the side of the range. The peak itself, however, rises nearly as a sharp cone for the last 700 or 800 feet without an obstruction on either side. Mt. Clay at the foot of this cone on the north is 5,500 feet, and the other mountains in the range are in the order: Jefferson 5,700 feet, Adams 5,759 feet, and Madison about 5,600 feet. On the south side the "Lakes of the Clouds" are at the foot of the cone 5,000 feet; and the other mountains are in order to the south: Monroe 5,900 feet, Franklin 4,900 feet, Pleasant 4,700 feet, and Clinton about 4,500 feet. This description shows that this range rises as a barrier to the flow of all air currents from the west, but at the immediate summit there is an opportunity for a flow of air on either side, and it is frequently noted that there is an increase of wind velocity just below the summit, especially on the north side. The base of the summit cone is roughly estimated at 1,500 feet.

A thermograph and barograph in addition to the usual thermometers and barometers were placed at the summit and two of the same instruments were placed in Fabyans, nine miles from the foot of the mountain on the west, and a barograph and rain-gauge were placed at the Glen House on the east.

The following are the principal facts observed:

Vertical Distribution of Temperature.—An attempt was made to obtain some knowledge of the temperature and humidity along the side of the mountain by walking down and observing the sling psychrometer at each mile and sometimes less. The most serious difficulty encountered was the existence of high winds blowing over the summit and up or down the deep ravines. These winds necessarily had their temperature and moisture affected by the surroundings, hence a rigid result could not be expected. Another difficulty arose from the immediate environment of each station on the mountain side. The only possible method of making such observations, where only one person was available, was to walk as rapidly as possible down the Glen House path and stop at each mile post long enough to

make a reading of the sling psychrometer. At times when the observer came out of a cloud between two stations a reading was made and condition of the weather was noted. The mile-post VII was situated on a rather level plain with a steep precipice on the north (left of the road), while VI had a steep mountain side on the right of the road and not much of a precipice on the left, and V was more like VII. It is easy to see that, under these conditions, only an approximation can be expected to the free air temperature and we cannot arrive at positive conclusions regarding it.

The following table I, contains the most important of these readings. In studying these observations we shall be safe in assuming that the mean of the readings on the way down and on the way back at each station will give the approximate mean at a common mean time for all stations, though this will not be exactly correct, since the time spent in walking down was almost invariably less than in going back. Only those who have walked over this road unmounted can be aware of the extreme weariness induced by such exercise.

TABLE I.

In this table f. stands for fog, d. f. dense fog, lt. f. light fog.

TIME.	PLACE.	WET.	DRY.	WEATH'R	TIME.	WET.	DRY.	WEATH'R
		July 10.				*July 11.*		
5 00	Summit.	48.5	49.3	fair.	7 05	50.9	50.9	d. f.
5 14	VII.	49.6	49.6	f.	7 26	52.3	52.3	d. f.
5 34	VI.	52.0	53.0	no f.	7 53	55.0	55.0	lt. f.
5 52	V.	53.0	53.0	d. f.				
6 03	Below V.	55.4	57.4	out of f.				
		Back.						
6 15	V.	51.0	51.0	d. f.				
6 39	VI.	51.6	51.8	lt. f.	7 59	56.0	56.0	lt. f.
6 59	VII.	50.6	50.6	f.	8 50	53.9	53.9	d. f.
7 22	Summit.	49.9	49.9	d. f.	10 13	51.5	51.5	lt. r.
		July 11.				*July 12.*		
15 32	Summit.	51.4	51.4	f.	7 22	46.0	46.0	d. f.
15 49	VII.	53.1	53.1	d. f.	7 40	47.8	47.9	d. f.
16 04	VI.	54.2	54.2	lt. r. d. f.	7 57	48.6	48.6	d. f.
	V.							
		Back.				Back.		
	V.							
16 07	VI.	53.0	54.0	lt. r. d. f.	8 03	48.8	48.8	
16 31	VII.	53.0	53.0	d. f.	8 24	48.0	48.0	lt. f.
16 53	Summit.	51.0	51.0	d. f.	9 01	47.1	47.1	f.
		July 13.				*July 15.*		
7 40	Summit.	48.3	48.7	lt. f.	10 10	36.3	38.8	
8 06	VII.	49.7	52.0	clear.	10 38	39.3	42.1	cloudy.
8 25	VI.	51.0	54.4	clear.	10 54	41.5	42.7	
8 51	V.	54.3	60.3	fair.				
		Back.				Back.		
9 23	V.	54.8	61.7	clear.				
9 55	VI.	54.4	59.8	cloudy.	11 05	40.3	41.8	cloudy.
10 39	VII.	53.2	55.4	cloudy.	11 25	39.4	40.8	
11 29	Summit.	51.8	54.0	cloudy.	11 50	35.8	37.8	

Time.	Place.	Wet.	Dry.	Weath'r	Time.	Wet.	Dry.	Weath'r
		July 16.				*July 16.*		
9 28	Summit.	39.3	39.3	d.f.	17 53	42.0	42.1	lt. f.
9 51	VII.	41.0	42.6	cloudy.	18 16	43.2	44.1	cloudy.
10 09	VI.	42.3	45.0	fair.				
10 31	V.	47.0	51.8	fair.				
10 39	Below V.	44.3	49.0	cloudy.				
		Back.						
10 45	V.	44.5	48.6	cloudy.				
11 08	VI.	43.8	47.0	cloudy.				
11 29	VII.	42.2	43.3	cloudy.	18 22	43.2	44.0	
11 52	Summit.	40.0	41.0	cloudy.	18 43	42.0	42.0	d. f.
		July 17.				*July 18.*		
7 57	Summit.	40.4	40.4	d. f.	7 16	43.7	44.3	lt. f.
8 08	VII.	41.8	41.8	d. f.	7 37	47.3	49.7	clear.
8 40	VI.	47.3	47.3	d. f.	7 53	49.0	53.3	clear.
9 04	V.	50.0	51.7	fair.	8 12	52.0	56.7	clear.
		Back.				Back.		
9 19	V.	48.0	50.8	fair.	9 25	53.0	55.3	cloudy.
9 49	VI.	45.8	47.0	fair.	10 00	50.3	53.0	clear.
10 20	VII.	43.7	43.8	d. f.	10 23	48.3	54.4	fair.
10 45	Summit.	43.0	43.0	d. f.	10 55	47.7	51.0	fair.
		July 18.				*July 19.*		
16 20	Summit.	47.0	51.3	clear.	8 28	48.8	51.7	clear.
16 43	VII.	50.0	55.4	clear.	8 52	50.4	54.0	clear.
17 02	VI.	51.2	57.6	clear.	9 20	51.8	58.3	
	V.				9 39	54.0	59.0	clear.
		Back.				Back.		
	V.				10 22	52.7	61.0	clear.
17 15	VI.	51.2	57.0	clear.	10 47	52.7	58.8	cloudy.
17 45	VII.	49.7	53.8	clear.	11 18	54.0	61.0	fair.
18 20	Summit.	46.6	49.0	clear.	11 47	50.2	56.0	fair.
		July 19.				*July 20.*		
15 38	Summit.	52.3	52.7	f.	7 18	51.9	51.9	d. f.
16 02	VII.	53.9	55.4	fair.	7 36	53.3	53.3	d. f.
16 19	VI.	54.6	57.4	fair.	7 54	54.8	54.8	d. f.
	V.							
		Back.				Back.		
	V.							
16 23	VI.	54.5	56.4	fair.	8 10	54.0	54.0	d. f.
16 55	VII.	52.6	55.5	fair.	8 19	53.6	53.6	d. f.
17 33	Summit.	52.0	52.0	d. f.	8 43	52.4	52.4	lt.r.
		July 20.				*July 21.*		
16 27	Summit.	49.7	49.7	d. f.	8 27	46.0	46.0	d. f.
16 50	VII.	50.6	50.6	d. f.	8 43	48.0	48.0	d. f.
17 04	VI.	52.3	52.3	d. f.	9 00	50.4	50.4	d. f.
17 20	V.	53.3	54.0	fair.	9 29	51.0	52.8	f. drift.
17 37	Below V.	53.8	54.3	cloudy.				
		Back.				Back.		
17 44	V.	53.7	53.7	d. f.	9 59	51.9	52.7	f. drift.
18 03	VI.	52.9	52.9	lt. r. d. f.	10 26	50.0	50.0	d. f.
18 25	VII.	50.1	50.1	d. f.	10 52	47.1	47.1	d. f.
18 43	Summit.	49.2	49.2	d. f.	11 18	46.0	46.0	d. f.
		July 22.				*July 22.*		
8 26	Summit.	47.7	50.0	fair.	17 01	52.5	54.0	cloudy.
8 53	VII.	50.8	53.7	fair.	17 21	53.6	55.4	fair.
9 09	VI.	51.9	54.4	clear.				
9 33	V.	54.2	57.6	cloudy.				
		Back.				Back.		
9 37	V.	53.7	57.3	cloudy.				
9 59	VI.	53.0	56 5	cloudy.				
10 32	VII.	52 7	55.0	cloudy.	17 58	53.3	55.1	cloudy.
11 37	Summit.	51.0	53.7	cloudy.	18 19	51.4	51.4	d. f.
		July 23.				*July 24.*		
7 18	Summit.	48.2	48.2	d. f.	7 14	33.6	33.6	d. f.
7 34	VII.	49.9	49.9	d. f.	7 30	35.4	35.4	d. f.
7 53	VI.	51.9	52.9	cloudy.	7 54	37.8	39.0	fair.
8 16	V.	53.3	54.6	cloudy.				

Time.	Place.	Wet.	Dry.	Weath'r	Time.	Wet.	Dry.	Weath'r
		July 23.				*July 24.*		
		Back.				Back.		
8 46	V.	54.5	54.7	fog.				
9 05	VI.	51.0	51.0	rain.	7 58	38.4	39.4	fair.
9 25	VII.	48.0	48.0	d. f. no r.	8 19	37.0	37.0	d. f.
9 44	Summit.	46.9	46.9	d. f.	8 40	34.7	34.7	d. f.
		July 25.				*July 26.*		
12 24	Summit.	37.8	40.5		8 12	37.3	38.4	lt. f.
13 22	VII.	39.2	41.7		8 37	41.3	42.7	clear.
	VI.				8 56	43.5	47.5	clear.
	V.							
		Back.				Back.		
	V.							
	VI.				9 14	44.2	48.0	
	VII.				10 05	43.2	47.0	
13 48	Summit.	37.7	39.4		10 43	42.0	43.8	
		July 27.				*July 29.*		
10 02	Summit.	41.0	41.0	d. f.	8 59	54.0	54.0	d. f. mist.
10 23	VII.	42.4	42.4	d. f.	9 15	56.1	56.1	mist.
10 40	VI.	44.4	44.4	d. f.	9 31	57.3	57.3	d. f.
10 58	V.	47.3	47.3	d. f.	9 47	58.6	58.6	d. f.
		Back.				Back.		
11 01	V.	47.0	47.0	d. f.	10 19	61.6	63.0	fair.
11 23	VI.	44.5	45.0	lt. f.	10 49	58.8	58.8	d. f.
11 43	VII.	41.8	41.8	lt. f.	11 10	57.2	57.2	d. f.
12 02	Summit.	39.7	39.7	d. f.	11 30	55.2	55.2	d. f.
		July 30.				*August 1.*		
9 17	Summit.	50.1	53.4	cloudy.	16 24	52.9	52.9	lt. r.
9 34	VII.	52.0	55.3	cloudy.	16 41	54.2	54.2	lt. r.
9 55	VI.	54.4	57.2	cloudy.				
	V.							
		Back.						
	V.							
	VI.							
10 15	VII.	55.0	55.1	d. f.				
10 38	Summit.	54.0	54.0	rain.				
		August 2.				*August 3.*		
10 16	Summit.	51.0	52.2	lt. f.	6 36	51.6	51.6	d. f.
10 38	VII.	54.3	56.7	fair.	6 51	53.0	53.0	d. f.
10 55	VI.	56.2	60.2	clear.	7 16	55.0	56.4	clear.
	V.				8 02	55.4	61.0	clear.
	Below V.				8 11	57.6	64.2	clear.
		Back.				Back.		
	V.				8 23	56.0	61.4	clear.
	VI.				8 46	56.0	59.0	clear.
11 27	VII.	55.0	59.0	clear.	9 06	54.5	57.4	cloudy.
12 00	Summit.	51.7	55.4	clear.	9 33	50.8	53.6	cloudy.
		August 9.				*August 10.*		
9 46	Summit.	45.6	45.6	d. f.	15 23	44.4	44.4	d. f.
10 02	VII.	47.0	47.7	fair.	15 47	46.3	46.3	cloudy.
10 17	VI.	48.5	50.0	cloudy.	16 01	48.3	48.3	lt. f.
	V.				16 16	49.4	51.0	clear.
	Below V.				16 26	50.4	52.0	fair.
		Back.				Back.		
	V.				16 34	49.2	51.0	fair.
	VI.				16 52	48.0	48.3	fair.
10 45	VII.	46.3	48.0	cloudy.	17 10	46.1	46.1	d. f.
12 07	Summit.	44.8	45.9		17 29	45.0	45.0	d. f.
		August 14.				*August 15.*		
9 05	Summit.	42.4	42.4	lt. r.	16 23	50.0	50.0	d. f.
9 19	VII.	44.0	44.0	lt. r.	16 39	51.0	51.0	d. f.
9 32	VI.	46.0	46.0	lt. r.	16 55	52.3	52.3	d. f.
9 46	V.	46.0	46.0	d. f.	17 10	53.3	53.3	d. f.
9 56	Below V.	47.4	47.4	lt. r.				
		Back				Back.		
10 16	V.	46.4	46.4	lt. r.				
10 25	VI.	44.7	44.7	lt. r.	17 27	51.8	51.8	d. f.
10 44	VII.	43.4	43.4	lt. r.	17 44	50.3	50.3	d. f.
11 02	Summit.	42.0	42.0	lt. r.	18 06	48.8	48.8	d. f.

TIME.	PLACE.	WET.	DRY.	WEATH'R	TIME.	WET.	DRY.	WEATH'R
		August 17.				*August 17.*		
7 51	Summit.	40.0	40.0	d. f.	15 51	40.0	40 0	d. f.
8 05	VII.	41.6	41.6	lt. f.	16 06	41.2	41.2	d. f.
8 22	VI.	44.7	45.2	cloudy.	16 21	42.7	42.7	d. f.
8 39	V.	45.8	49.0	clear.	16 46	45.0	46.0	fair.
	Below V.				16 58	45.0	45.7	fair.
		Back.				Back.		
8 51	V.	47.4	49.9	fair.	17 16	43.9	45.4	fair.
9 14	VI.	44.6	45.9	cloudy.	17 39	42.0	42.6	cloudy.
9 34	VII.	42.7	42.7	d. f.	18 02	41.0	41.0	d. f.
9 54	Summit.	41.2	41.2	d. f.	18 23	40.0	40.0	mist.

All the readings were made by the same person. It should be noted that the difference in height between the mileposts, determined by a delicate aneroid, was 500 feet summit to VII; 550 feet VII to VI; and 500 feet VI to V.

After taking the mean temperature at each station for each journey down and back, the mean temperature at the summit for the thirty-four cases was taken and found to be 47.1 and at VII it was 49.2. This difference 2.1 gives a rise of 1° in 238 feet.

In the same way the thirty readings at summit, VII and VI gave 47.1°, 49.3° and 51.4° respectively, and a rise of 1° in 227 feet between summit and VII and of 1° in 262 feet between VII and VI. The nineteen readings at all four stations gave 47.1°, 49.0°, 51.3° and 53.8° respectively, with a rise of 1° in 263, 239 and 200 feet. Taking the sixteen journeys when the air was not saturated we find the values 48.0°, 50.7°, 52.9° and 55.5° respectively, or a rise of 1° in 185, 250 and 192 feet. On days when the air was saturated we have 46.2°, 47.7°, 49.7° and 51.8°, with a rise of 1° in 333, 275 and 238 feet.

Table II gives these values in a better form for study.

	No. of Obs.	Temperature. Sum.	VII	VI	V	Rise of 1°, No. feet. Sum. to VII	VII to VI	VI to V
All to VII.	34	47.1	49.2	....	....	238	....	....
All to VI..	30	47.1	49.3	51.4	....	227	262	....
All to V...	19	47.1	49.0	51.3	53.8	263	239	200
All dry....	16	48.0	50.7	52.9	55.5	185	250	192
All wet ...	14	46.2	47.7	49.7	51.8	333	275	238
Theory wet.....	....	....	....	....	....	381	373	364

We see that in the cases with partly dry air this table does not differ widely from the theoretical value, but with moist air the theoretical difference per 100 feet is much less than the observed difference, especially at the lowest station. This latter result may be partly accounted for from the fact that on several days the air was not saturated below VI.

[TO BE CONTINUED].

CYCLONES AND TORNADOES IN NORTH AMERICA.

BY JOSEPH BRUCKER.

It is a well known fact that cyclonic movements in the different parts of our globe follow different directions.

When speaking in this paper of cyclonic movements, I have in view only such as occur in the United States, *east of the Rocky mountains*, and whose origin I attribute to the following principal causes:

1. Solar radiation.
2. The tradewinds of the Atlantic ocean which are deflected towards the northwest and north by the high mountainous ranges of Central America.
3. The ascending warm and moist air with its centrifugal motion around the unstable foci of tradewind curves.
4. The falling, cold and dry air, with its centripetal motion towards the depression (Low.)
5. The mutual impetus effected by the collision of these two contrasting air movements.

Many other factors, indeed, have to be considered in connection with the above mentioned principal causes of cyclonic movements, storms and the climate of the United States, for instance: The tradewinds of the Atlantic Ocean, the northeast trade as well as the southeast trade, are changing their relative positions to the equator during the different seasons; the region of calms between the southern limit of the northeast tradewind and the northern limit of the southeast trade has a different position and extension during the different seasons; solar radiation and the seasons are changing the *energy* with which the tradewinds are pushing themselves northward; the western curve of these tradewinds may run over the West Indies, traverse Yucatan, or run along the Atlantic slope of the Mexican plateau.

The meteorological conditions of the Mexican Gulf, the Caribbean Sea and their bordering country south and west with the Antilles in the east, are of the greatest importance. An important factor is also the gradually *rising territory* from the Gulf States towards the Rocky mountains and the big plains in the far northwest, are extremely favorable to the movement of the rising warm and even more so to the falling cold air currents. The territory east of the Rocky mountains belongs to

an entirely different wind system from that of the Pacific slope.

The relation of mountain ranges to air currents is the same as that of the coast and its submarine trends to ocean currents.

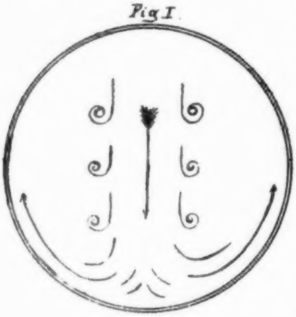
Having now briefly outlined the basis on which I intend to form my theory I may proceed to say, that *the movements of the atmosphere are analogous with those of liquids*, the cyclonic movements of the air analogous to the great ocean currents, the tornadoes or local air whirls of great force analogous to water whirls.

Such whirls are always produced in the *tranquil* air (or liquid) along the outer curve and in the rear of the flowing current.

To substantiate my theory it is unnecessary to employ the expensive apparatus and rather complicated experiments of *Weyher* (as published in the May number of the JOURNAL.) A simple washtub filled with water into which a fine sediiment of sand and soot should be thrown, so that it may easily be stirred up by a shingle or small board, will be suficient to illustrate certain motions in fluids as well as in the atmosphere.

The washtub, which I used for the experiment, was one of ordinary size, 24 inches in diameter on top, 20 inches on the bottom and 12 inches high. It was filled with rain water which, coming from the roof of my house, had collected some fine sand, soot and pigeon manure, which being but little heavier than water, was stirred up easily by the least motion of the water.

Fig I



To bring the water in motion used a common shingle about six inches wide.

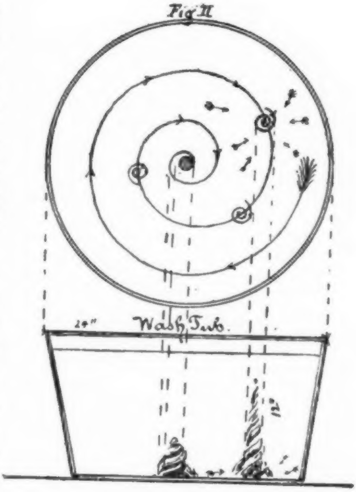
A straight movement through the center of the tub produced the well known whirls as shown in Figure 1.

I have frequently had occasion to study these same movements at the gates of our Black River dam and Table II will give the reader an idea of my observations.

Figure 2, page 401, illustrates the effect of moving the shingle perpendicularly and close to the side of the tub through the water in about a semi-circle. The soot and sediment which has rested quietly on the bottom of the tub is drawn into

the main spiral curve (cyclone) towards the center of the tub, *but has its own gyrations which are helicoidal spirals* and the sediment ascends at times as high as the surface of the water. Whenever the centripetal force of this small but very getic whirl is exhausted the particles of sediment sink and move on for a distance along the main spiral, when suddenly the gyration becomes stronger again and the same process is repeated. At last every particle of sediment is collected at the center of the bottom.

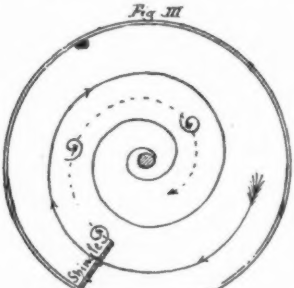
Fig II



During the time the formation of whirls along the main spiral-curve is going on, the little particles of sediment, which had been distributed all over the bottom of the tub, fly with great velocity from all directions towards the centers of these whirls.

A very interesting experiment also is illustrated in the accompanying Figure 3. The water is brought into motion as described before (Figure 2). Then the shingle or board is held vertically in the water and close to the wall. Instantly a very strong whirl is produced at the outer edge, whose center moves along the the original spiral curve, *but whose gyrationsre in the opposite direction.*

Fig III



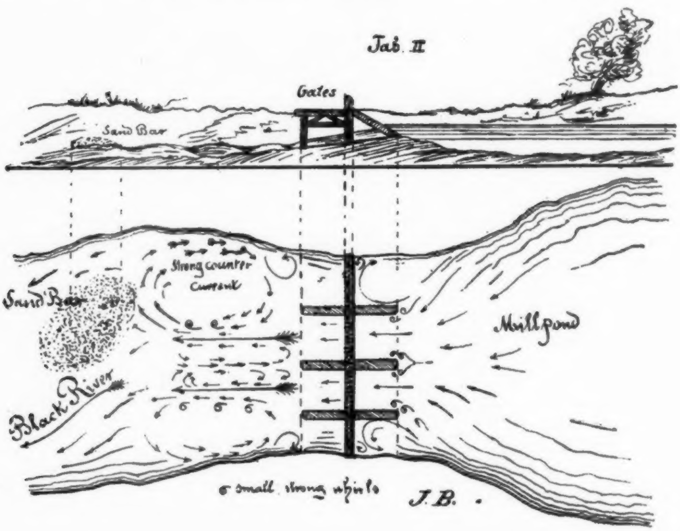
The observations I have made in Black River, the washtub or even the teacup, when ever the spoon was moved through the tea showing the particles of cream gyrate behind the spoon; the whirl produced in

the quiet corner of a building slightly retracted from the front of the street through which a light wind was blowing and many other similar instances have led me to the following conclu-clusions:

1. Every movement in liquids or gases causes gyrations on its flanks and rear.

2. Tornadoes may occur where the falling cold and dry "Northers" meet the rising, moist and hot air. (Table III).

3. Tornadoes most likely originate above the overheated surface of the earth in a calm atmosphere* (never where a brisk



wind is blowing). This calm atmosphere must be in the rear of the aerial contest above described. (Table III).

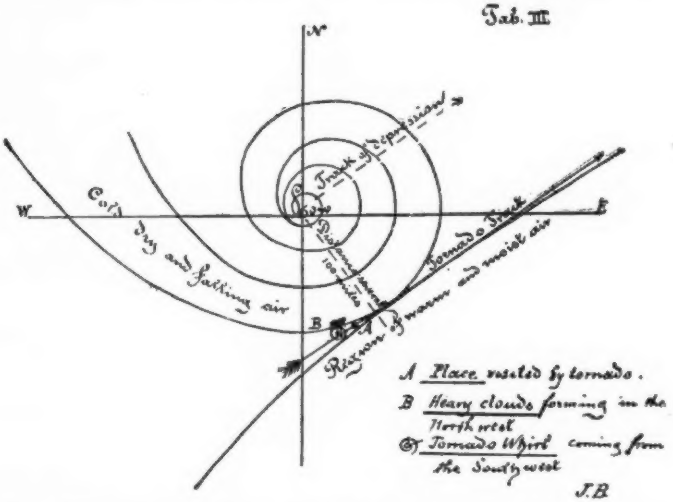
4. The tornado region moves with the sun, northward from April to August, southward during fall and winter.

5. During the summer the main course of the "hot wave" runs far west of the Mississippi, turns then northeasterly, and is oscillating over a territory embracing Missouri, Kansas,

*Finley gives in his "Report on the character of 600 tornadoes" the temperature preceding storm always as "very sultry," "sultry," "very warm," "oppressive," "very hot"; whereas the temperature following is given as "chilly" or "cold" without exception.

Nebraska, Illinois, Indiana and Ohio. During the "dog-days" advances further north, reaching Minnesota and Wisconsin.

During our winters, when the middle and northern states are covered with snow, and by radiation extreme cold reigns over this continent so that even Texas, lying in the latitude of Egypt, is suffering from the visit of the icy northers, then the NE trade takes a more southwesterly course, and its ally, the SE trade, instead of switching to the northwest is flowing to the southwest; the tradewind curve becomes trough-like and its long axis trends more from SSW to NNE. Then the hurricanes in the West Indies, and the tornadoes in the southern states write their destructive and instructive lesson through



the wilderness and the cultured fields, killing, wounding and demolishing everything in their path.

In conclusion I want to state that I fully endorse the opinion of Mr. Finley, "that the forecasting of conditions favorable to the development of tornadoes and designating the quadrant of a state in which such conditions shall give rise to local signs that the inhabitants of that section can rely upon, is entirely practicable," * but I am also of the opinion that our present observations are not sufficient and that more information is needed from

* American Meteorological Journal, August, 1890, p. 178.

the northern coast of South America, the West Indies, Yucatan and the eastern slope of Central America. The low peninsula of Yucatan has a dominant position between the Gulf of Mexico and the Caribbean Sea, and a well organized station at Cape Catoche would certainly be of great service to our Weather Bureau.

As the radiation of the sun is changing its energy during certain periods of sunspot maxima, a record of these changes and of their effect on ocean and air currents should be kept, and I hope that in the near future Mr. McAdie's expectations will be realized when he says: "As it was from the perturbations of the planet Uranus that Adams argued the existence of the planet Neptune and Leverrier directed the Berlin astronomer where to look to find it, so, we believe, it will be from a most careful and detailed study of these secondary whirlings in our atmosphere, that the seeming irregularities and uncertainties of the primary whirlings will be made known; and the prediction, not alone, of storms of marked intensity as *e. g.*, tornadoes, thunderstorms, etc., be made possible, but the ordinary predictions of general weather conditions be made eminently successful."*

MEDFORD, WIS., August, 1890.

THE COOLING OF DRY AND MOIST AIR BY EXPANSION.

BY PROFESSOR C. F. MARVIN.

In a recent work entitled "The Tornado," Professor Hazen has presented a chapter devoted to the discussion of various "objections" he raises against certain theories advanced in connection with tornado development, and in a following chapter he reviews some of Espy's experiments and gives also results obtained by himself that lead him to certain remarkable conclusions.

On page 52, speaking of the principle that moist or saturated air in expanding is warmed by the latent heat set free from that portion of the vapor that is condensed by the expansion, he says: "There is nothing in the science of meteorology, or possibly in any physical science, that has been developed from such a worthless origin as this theory of the liberation of energy on the condensation of moisture." Of his conclusion, he says: "We have arrived at precisely the same result both by most

*This JOURNAL, August, 1890, p. 192.

careful experiment and by an unanswerable train of reasoning. The proof is overwhelming that this great source of energy" (the condensation of vapor) "amounts to nothing whatever." Thus the thoroughly tested and established principles of thermodynamics are set aside with a breath.

A little consideration leads me to the opinion that Professor Hazen's "most careful experiments" are none the less seriously defective and his "unanswerable train of reasoning" includes some very grave errors, as I hope to show by what follows.

I do not consider that the principles of thermodynamics need any defence whatever on my part, and simply wish to call attention to one or two phenomena that may possibly have accompanied both Espy's and Hazen's experiments upon the expansion of dry and moist air, and of which no mention is made by others.

The conditions of experimentation are these: A large glass jar of two or three litres capacity is fitted with an ordinary U tube mercurial manometer capable of indicating pressures amounting to four or five hundred millimeters above the atmospheric pressure. The glass jar is also fitted with a stop-cock and apparatus for compressing the air. In the experiments after compression the stop-cock is opened, allowing the more or less rapid escape of the air, which is accompanied by a more or less rapid fall of the mercury in the tube. When the mercurial columns are on a level, or at any other desired position, the stop-cock is closed, and it has been assumed that the pressure of air in the jar was that indicated by the particular position of the mercurial column at the instant the stop-cock was closed. Shortly after this the mercury is found to rise more or less; presumably by the warming of air previously cooled by expansion.

Professor Hazen in his writings has already credited me with having personally suggested to him that the rapidly falling mercurial column could not be considered as following closely the rapidly falling pressures of the expanding air, which might be much slower in reaching its equilibrium than the mercurial column, so that a part at least of the subsequent rise of the mercury might be due to this. Little thought was given the matter at the time, but it has been further considered in connection with Professor Hazen's article in the September number of this Journal and his book on "The Tornado." The importance of the suggestion may be judged by what follows.

Let the initial pressure in the jar, as indicated by the height of the mercurial column, be represented on the diagram by the distance of the point P above the axis of X, or line of atmospheric pressure. Let intervals of time be measured horizontally.

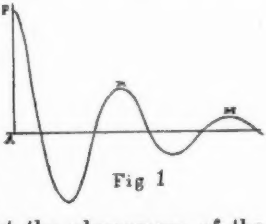


Fig 1

Now, let the initial pressure be *instantly* reduced to atmospheric pressure. The rate of fall of the air pressure will then be represented by the line PA. From the principles of mechanics we learn that the phenomena of the fall of the mercurial column may be represented by the harmonic line PMM. If the pressure of the air is not instantly reduced but follows some such law as that indicated by the line PA of figure 2, it can easily be shown that the harmonic movement of the mercurial column is superposed upon the pressure line PA, and may be represented by the line PMM in figure 2. It is not considered necessary to give any demonstration of these statements; one only needs to watch carefully a more or less rapidly falling mercurial column and the various phenomena are perfectly apparent to the unaided eye. The column appears to suddenly halt in its downward motion and then starts off again. The time of vibration is determined principally by the whole length of the column and ten or more vibrations are easily counted in a fall of 400 mm. of a column a little over 400 mm. long and some of 5 mm. diameter; the whole time being ten or twelve seconds. If the free flow of the mercury is restricted, as by the use of tubes of small internal diameter, the vibrations are reduced in amplitude but are plainly visible in tubes as large as those used by Professor Hazen, notwithstanding which the phenomenon seems to have escaped his attention, and no mention of it is made by Espy, though he may have taken precautions against its effects.

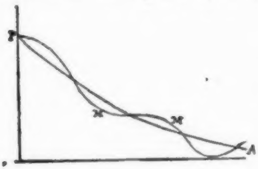


Fig. 2

In this connection it should be noted that the volume of the manometer tube should be small in comparison with that of the receiver, otherwise an appreciable correction may be necessary

to allow for changes in volume corresponding to changes in the position of the mercury.

We are led to conclude from the above that the mercurial manometer is a very untrustworthy device to use in observing the rapidly changing pressures of an expanding gas, and that, in many cases, the pressure of the air may be considerably above the outside pressure at the instant the mercurial columns reach a level. A suitably arranged steam engine indicator is, of course, the thing to use.

Wishing to examine this subject farther, I hastily prepared a pressure gauge free from these defects. This was made of the vacuum chamber of an aneroid barometer. The little outlet tube, always found on the side of these aneroid shells, was opened and extended so that the inside of the shell could be put in communication with the glass jar. On compressing the air the shell distends appreciably. Its motion is sufficiently magnified by a long very light lever made up of a capillary glass tube, the end of which passes over the divisions of a scale. Thus we have a rudely constructed gauge capable of following instantly, and without sensible vibrations, the varying pressures of the expanding gas. It is used in conjunction with the mercurial gauge, both being attached to the jar, and is employed principally to determine when the air in its expansion has reached its equilibrium with the outside.

Let figure 3 represent the case of air having an initial pressure of about 400 mm. in excess of atmospheric pressure, expanding in four or five seconds' time; conditions comparable with those in Professor Hazen's experiments. The following considerations present themselves:

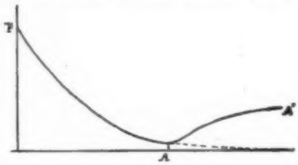


Fig. 3.

The gas is cooled by expansion.

It absorbs heat from the surroundings; slowly at first, when its temperature is but little below that of the surroundings; more rapidly at the last when its temperature is considerably lower than that of the environment. At the last the fall in pressure is slow by reason of the small difference in pressure between the inside and outside. The rapid absorption of heat at this part of the operation tends, moreover, to keep the pressure up, and it therefore results that, in the latter part of the expansion there comes an instant when the diminution of pres-

sure due to the escape of the air is balanced by the increase of pressure resulting from the absorption of heat. This condition is maintained during an appreciable time, and the pressure itself is perceptibly above the outside pressure. All this action is made perfectly apparent by the aneroid gauge. The stop-cock is turned the instant the gauge reaches its lowest point, or better still, when the index reaches a certain low point, the corresponding pressure being noted. This quantity should be subtracted from the subsequent rise of pressure.

It is found that the mercurial column not only reaches a level condition before the air has completed its expansion, but actually performs one or two vibrations before the aneroid gauge indicates the end of the expansion.

If it is desired by this method of expansion to detect a possible difference between the cooling of dry and moist air, it seems advisable to remove the objectionable elements I have thus pointed out. These defects I think have undoubtedly been present in Professor Hazen's experiments, and possibly in those of Espy, though many important details of his apparatus and experiments are unknown, so that it is difficult to say to what extent his numerical values may be inaccurate by reason of such defects. He seems to have found a real difference between wet and dry air, and this is not only in accord with established thermodynamic principles, but is easily obtained, experimentally, if some care be used to eliminate such errors as those referred to above.

I have made no pretentions to a duplication of Espy's experiments. Many important details of his apparatus are unkown, but the experiments made, as described above, are capable of giving correct results that agree, in the main, with Espy's, so that it is a reasonable presumption that his experiments are not so defective as Professor Hazen's attempted duplication.

On page 67, Professor Hazen makes some remarks upon the difficulty of saturating the air in such experiments as these. He seems also to doubt very much that Espy obtained saturated air. A few considerations lead me rather to think that under many circumstances *it is almost impossible to avoid saturating the air*, and I have even to suggest that Professor Hazen's failure to obtain the noticeable difference between wet and dry air is possibly due to the fact that he did not succeed in *drying* the air.

In these experiments on the compression of the air, I will

endeavor to show that the mere action of compression alone is, in many cases, sufficient to even more than saturate the air; thus, for illustration, take the case of a compression to 400 mm. in excess of the atmospheric pressure. Take the temperature at 70° and let the relative humidity be 70 per cent. Suppose the barometer stands at 760 mm. The pressure of the aqueous vapor under these circumstances is easily found to be 13.0 mm.

We have then, before compression—

Air pressure, 747 + vapor pressure, 13.0 = 760.

And after compression—

$$747\,\frac{1160}{760} + 13\,\frac{1160}{760} = 1140 + 20 = 1160.$$

The maximum vapor pressure possible at 70° is nearly 18.6 mm., and it therefore appears, as soon as the gas has cooled down to 70° after the compression, it is more than saturated and a portion of the vapor is obliged to condense and become visible. Indeed, it is easily seen to form a slight mist, or dew upon the walls of the glass jar. I am more than surprised to find that so important a phenomenon should have escaped the scrutiny of one repeating the experiment a great many times.

In the above demonstration it is assumed that the aqueous vapor during compression follows the usual laws for more perfect gases. No error of any importance in this connection is introduced by the inaccuracy of this assumption.

There can certainly then be no difficulty in saturating the compressed air. Yet Professor Hazen claims that the only feasible plan is to force the air through a wet sponge. If, however, a bottle of saturated sponge is used, the air should be forced through a sponge *before*, not after, compression. The same conditions should be observed in drying the air. A greater volume of air is exposed to the chemicals in this case.

It appears further that Professor Hazen has made a grave error in his apprehension of the actual theoretical heating and cooling of gases by compression and expansion. On pages 64 and 68 he states the theoretical heating or cooling due to a compression or expansion of ten inches to be 163°. This is about the amount a gas would need to be heated if its volume was kept constant and its pressure raised to ten inches above atmospheric pressure. Conversely, the presumed cooling of 163° is the amount a gas would have to be cooled if its volume was changed to the proportion of 40 to 30, the pressure remaining

constant throughout. His numerical computations of the heating and cooling are all entirely wrong. It seems he has wholly misapplied a thermodynamic equation appropriate to an entirely different problem.

The actual cooling corresponding to an expansion from a pressure ten inches in excess of the atmospheric pressure, would be about 42° for an initial temperature of 70°. The subsequent rise in pressure as the gas returns to its initial temperature would be about 3.0 inches.*

We may sum up then the following points in which Professor Hazen's arguments are open to criticism:

1. The mercurial gauge is very ill-suited to experiments of this kind, and in the hands of one unaware of the phenomena of its movements is liable to give misleading results.

2. That no real difficulty exists in saturating the compressed air in such experiments as these.

3. That it is quite probable that Professor Hazen in no instance experimented with practically dry air in a dry vessel. These conditions are really difficult to secure, as most physicists are aware. Professor Hazen even asserts that he succeeds in forming a visible cloud in practically dry air and surmises if the substance of the cloud may not be dust. There is but the slightest doubt that the cloud is pure water. His reliance upon his method of measuring the relative humidity may possibly have misled him and there was more moisture present than he supposed.

4. That his calculations of the theoretical heating and cooling of gases are not made by the proper thermodynamic equations and are incorrect.

I am aware of other defects in Professor Hazen's work, but if the above are corrected it seems his chapter on "objections" will have but a frail foundation, and his experiments will lead him to different conclusions.

The arguments presented herein are strongly in support of the accuracy of the conclusions reached by Espy. Professor Hazen offers a prize of one hundred dollars for the proof of the proposition: That Espy's experiments, when properly interpreted, prove his theory.

WASHINGTON, D. C., Sept. 29, 1890.

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*Shortly after the above was written, Professor Ferrel's article in *Science* and more recently in the November number of this JOURNAL calls attention to this same error, and gives 43° as the cooling. The difference of 1° in our values arises from neglecting fraction of a degree. My calculation gave me 42°.5 the 0°.5 being dropped.

ACCESSORY PHENOMENA OF CYCLONES.

By H. Faye,
Membre de l'Institut, Président du Bureau des Longitudes, etc.

(CONTINUED).

Electricity in Tornadoes.—The tornadoes which are born in in the clouds the midst of rain and hail, are not organs for the production of electricity, because they do not contain cirrus. They carry with them, at the most, the electric charge of the portion of cloud which is engulfed in their descending spirals. This is confirmed, it seems to me, in Mr. Finley's statistics: "Electrical discharges were observed in two hundred and fifty-two cases, as occurring in the clouds surrounding the tornado, that is, in the clouds near the horizon, and in eighty-four cases as occurring in the funnel-cloud. Tornadoes do not produce lightning strokes; but certain *trombes* present very curious electric phenomena when they do not touch the earth. Balls of fire sometimes escape from the point of the cone, and move slowly away in the atmosphere until they are dissipated in the air, or burst with a detonation in the encounter with some obstacle.

These balls of fire resemble, according to the hydrographic engineer, M. de Tessan, a Leyden jar strongly charged, rather than an electric discharge, or a flash of lightning.

This is, I think, the explanation of these rare and, at first view, enigmatical phenomena. When the tornado touches the earth, the electricity which it brings downward is lost in contact with the earth; but if the tornado rises (because the generating current weakens) it will reform immediately as a sack, (see Mr. Finley's illustrations) while all the relatively dry air of the narrow interior canal, which corresponds to the central calm of cyclones, tends to continue its descent. The point of this sack will receive a shock like a blow which will produce a small swelling. This swelling may detach itself and, on account of the extremely rapid gyration of its cloudy envelope, form a spherical ball, isolated and independent, composed of two parts: a mass of air in the interior which is relatively dry, coming from a region situated above the mouth of the tornado; and a cloudy stratum outside, proceeding from the cloud sheath of the tornado and its internal spirals, which is strongly electrified oppositely to the internal mass. In this double apparatus, of which the very thick superficial stratum is animated by rapid gyratory movements, there should be produced a re-composition

of the opposite electricities through the mass, which is a poor conductor of electricity. This gives rise to a light which makes the ball visible. As these two electricities are dissimilar in the entire apparatus, this ball will have no tendency to pass over the conducting bodies; and as its density differs little from that of the air, it will descend or ascend as if at hazard, according as the heat coming from the slow recomposition of the two electricities renders it heavier or lighter than the surrounding air. Finally if it encounters a penetrating obstacle, it will discharge like a Leyden jar; the heat thus produced will suddenly reduce the cloudy particles of the envelope to vapor and produce an explosion.

Mariners are sometimes witnesses of these phenomena, to which they have given, I think, the name *corposant*. It is for them to judge whether this explanation is a satisfactory one.

Small Cyclones in Other Parts of the World.—Aside from cyclones proper, and the typhoons of the extreme orient, lesser storms are produced in different regions to which various names have been given. Such are the tornadoes of the west coast of Africa; the arched squalls of Malacca; the pamperos of South America; the dry storms of Arabia and the Great Desert of Africa, known as the Khamsin or Simoom; the great whirls of the steppes of Tartary; the dust storms of Bengal, Mexico, and the dry interior of Australia. All these phenomena present, like cyclones, a gyratory movement and a vast movement of translation. The mechanical phenomenon is everywhere the same: the differences consist only in the physical conditions which we entirely neglect.

All gyratory movements susceptible of being seen in their entirety, *trombes* or tornadoes, are clearly defined by surfaces of revolution of conical form. Is not the same true of cyclones whose contours we cannot see? The difference of form is such that one might hesitate in comparing one to the other.

Let us examine the small cyclones like the *travados* which formerly wrecked the vessels of Portuguese navigators. The following description is due to Dr. Barius, a physician in our marines.*

"A *travado*," says the author, "comes most frequently after a day of excessive heat. The southwest wind which predominates during the day has given place to a calm in which the wind-vane indicates for a few minutes, a faint wind from the

* *Recherches sur le climat du Senegal.* Paris, 1875.

north or northeast. In spite of the direction of the wind, which generally produces a cloudless sky, the southern horizon grows dark; a black cloud of small extent * appears in the south and southeast and indicates the formation of a *travado*. After a lapse of time, varying from two to four hours, this black mass begins to move slowly in a direction nearly from south to north, and the part of the sky which it covers, increases in size. When the mass of nimbus reaches about 25° above the horizon it forms a regular semicircle, beneath which the sky can at times be seen.

"The edge of this moving mass has the appearance of a ring. Its convexity faces the north, while its lower ragged part faces the south. It advances with a proper motion in a direction contrary to the light breeze which blows from the south. At 45° from the zenith it offers a most characteristic appearance. It is a vast black circle, a sort of mushroom shape, with a foot which is seen at three quarters and from below.

"The contours are well defined in front and on the right and left edges, but ill-defined in the rear, in that part which touches the horizon. The clouds are at times, though rarely, furrowed by lightning flashes; thunder is seldom heard.

"When the anterior edge reaches the zenith, or when two-thirds of the sky is covered, a wind of extreme violence is unloosed at the earth's surface and blows from the southeast, and the meteoric mass has no longer a definite form. The storm lasts a quarter of an hour at the most, during which the wind backs to the east, then to the northeast, to the north, northwest, and finally to the southwest. Its velocity of translation is about fifteen leagues per hour."

It is evidently a small cyclone whose trajectory is perhaps recurved toward the seventeenth or eighteenth degree of latitude. This description shows the circular character of its contours.

I have studied the arched squalls which are encountered in the East Indies and sometimes in Europe, and have arrived at the same conclusion. The difference consists in that the *travado* described by Dr. Barius passed over the head of the observer, while the arched squalls are *travados* whose trajectories remain at some distance from the place of observation and which seldom reach the zenith. The same is true of the *pamperos* observed [illegible] the coast of Buenos-Ayres or on the La Plata.

*This is the cloud which the Portuguese call the "Bull's Eye," *Olho de Boi*. H. F.

I have found in the Bible, Kings I, Ch. XVIII, a description of a real *travado*. It is after the three years of famine which desolated Palestine in the time of Ahab. Elijah had come to announce to the King that the end of the drought was at hand. All Israel had assembled in the region of Mt. Carmel. 43. And he said to his servant: "Go up now, look toward the sea."

And he went up and looked, and said: "there is nothing." And Elijah said: "Go up again seven times."

44. The seventh time he said to him: "There is a little cloud like a man's hand which ariseth from the sea."

Then Elijah said to him: "Go up, say unto Ahab, 'Prepare thy chariot, and get thee down, that the rain stop thee not.'"

45. And it came to pass in the meanwhile that the heaven was black with clouds and wind, and there was a great rain.

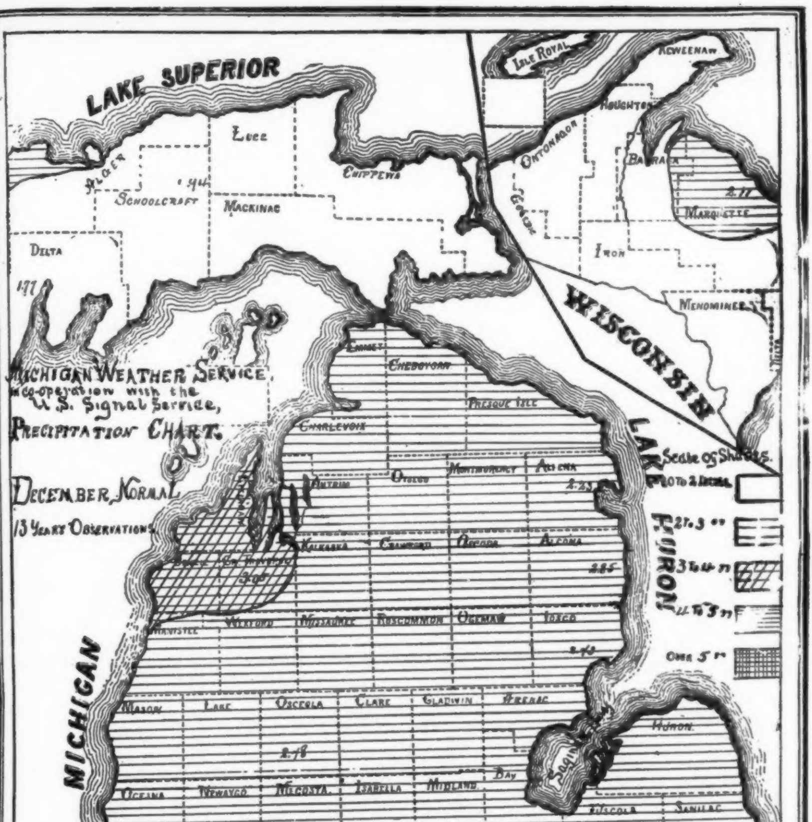
From Mt. Carmel the sea is visible to the west; the small cyclone came from there with great velocity. What looked at the horizon like a man's hand was the stratum of clouds formed below the invisible mouth. The wind and the rain came when the sky was covered by that stratum. Nothing essential is lacking in the short Bible account. The arrival of this storm was the signal for a permanent change in the weather which caused the cessation of the famine.

This little oval-shaped cloud, similar in everything to the "bull's eye" of the African *travados*, as well as the storms coming in the form of a huge mushroom, assumes clearly a regular form, a figure of revolution; and if the small cyclones are thus defined like *trombes* and tornadoes, it may be boldly concluded that such is also the shape of the large cyclones.

If storms, cyclones, typhoons, *travados*, etc., originated below and developed little by little, in a given place, for example, as the result of persistent insolation, and then put themselves in motion with the speed of a locomotive,—it certainly would happen that among the millions of spectators, at least a few would be found who had witnessed their formation and would have seen them develop, more or less rapidly, near the ground. This has never happened. Storms form above and beyond our sight, when they reach us, it is with all their violence if not with all their grandeur.

The same may be said of *trombes* and tornadoes and with still better right: they are seen to form above and descend from the clouds, and when they reach us, they come with all their force.

(TO BE CONTINUED.)



MICHIGAN WEATHER SERVICE,
in co-operation with the
U. S. Signal Service,
PRECIPITATION CHART.
DECEMBER, NORMAL
13 Years Observations.
Scale of Shades.
LAKE SUPERIOR
LAKE MICHIGAN
LAKE HURON
WISCONSIN
INDIANA
OHIO
Lake Erie.
Isle Royal
Keweenaw
Houghton
Ontonagon
Baraga
Marquette
Iron
Menominee
Alger
Luce
Schoolcraft
Mackinac
Chippewa
Delta
Emmet
Cheboygan
Presque Isle
Charlevoix
Antrim
Otsego
Montmorency
Alpena
Kalkaska
Crawford
Oscoda
Alcona
Wexford
Missaukee
Roscommon
Ogemaw
Iosco
Mason
Lake
Osceola
Clare
Gladwin
Arenac
Huron
Oceana
Newaygo
Mecosta
Isabella
Midland
Bay
Tuscola
Sanilac
Muskegon
Montcalm
Gratiot
Saginaw
Kent
Genesee
Lapeer
St. Clair
Ottawa
Ionia
Clinton
Shiawassee
Oakland
Macomb
Allegan
Barry
Eaton
Ingham
Livingston
Van Buren
Kalamazoo
Calhoun
Jackson
Washtenaw
Wayne
Berrien
Cass
St. Joseph
Branch
Hillsdale
Lenawee
Monroe
2.90
2.50
2.25

RAINFALL IN MICHIGAN—DECEMBER.

By N. B. Conger,
Director State Weather Service.

The precipitation for the month of December is evenly deposited over the lower peninsula, the amount averaging 2.60 inches with the exception of the district round about the Traverse Bay region where the amount ranges above three inches.

In the upper peninsula the average amount for the district is less than two inches, and this is probably because the majority of it is deposited in the form of light snow, which occurs frequently, but the amount is small.

The largest amount of precipitation occurred in 1884, when the amount for the state was 4.85 inches, and the maximum amount of 8.65 inches was recorded at Marquette. In the south half of the state, 6.59 inches is the largest amount recorded at any one station during the past fifteen years, the amounts for each year being near the normal.

As has been before stated in these papers, it is to be greatly regretted that there has been no record of the amount of snowfall on the level, or the amount on the ground at the close of the month which is available, as now, and which would be of no little importance in computing the effect of the normal precipitation on the different cereals of the state, and which has an important bearing on the wheat producing districts of the state, but as these records are now made, their value will become apparent as soon as there are records enough to compute a substantial normal form.

CORRESPONDENCE.

OBSERVATION OF A SMALL ATMOSPHERIC WHIRL.

To the Editors: At ten minutes before noon to-day while sitting on my porch looking towards the east my attention was attracted by a violent rustling of dry leaves on a tree, situated on the edge of a small oak grove, about 300 or 400 feet SE of my location. The air in the shade was mild, but in the sun it was quite warm, after a cool night; there was just enough wind

from the south to make the leaves move, but their frequent fall was almost directly towards the earth. The wind which so suddenly rustled the leaves on the individual tree in question proved to belong to a small atmospheric whirl which, in a few seconds, had stripped nearly all of the partially dry leaves from a full foliaged tree, and as the whirl slowly passed over a little clearing in a direction from south towards north, it carried the leaves with it, and I had the best opportunity which has ever presented itself to me for watching the motions in a whirl of considerable size.

The progressive motion of the whirl was from S. towards N., and the velocity of translation was not over seven or eight miles per hour. The diameter of the whirl, as shown by the hundreds of leaves, was perhaps 40 or 50 feet, and the altitude 100 or 120 feet, (probably more nearly the latter). Some of the leaves moving around in circles must have had a velocity of 20 or 25 miles an hour, and at about the center of the whirl there was a strong upward current. One very large leaf which I noticed being carried up, had, at a point 70 or 80 feet above the ground, a motion *straight upwards* of at least 10 miles per hour. (This leaf was evidently a large oak leaf while all of the rest were much smaller leaves).

As the whirl progressed leaves fell almost straight to the ground in its rear, just as if they had been carried up by a central current, and when the power of this had ceased and they fell back again towards the ground, the whirl had passed from beneath them, and they fell in quiet air. The direction of the whirl was counter-clockwise.

After crossing the little clearing the whirl entered another woods, and I could hear rustling of the leaves as it stripped them from the trees in its path. Had I been able to follow it I could probably have observed its motions for several minutes; as it was I saw it for only half a minute.

About three or four minutes after the passage of the whirl (which was immediately followed by an almost calm) a fairly strong breeze of six or eight miles per hour set in from the south, but it was not of long continuance. Elevation above sea level 2,700 feet.

FRANK WALDO.

MT. LAKE PARK, GARRETT CO., MARYLAND, Oct. 9, 1890.

CURRENT NOTES.

THE AMERICAN CLIMATOLOGICAL ASSOCIATION held its last meeting at Denver in September. Its proceedings will be printed by *The Sanitarian* of New York.

THE AMERICAN PUBLIC HEALTH ASSOCIATION held its eighteenth annual meeting at Charleston, S. C., on December 16, 17, 18 and 19. Its programme included the discussion of climates favorable for consumptives. Dr. Henry B. Baker is president. The association has published a good portrait of its president.

HEIGHT OF CLOUDS.—The following is from a letter from Mr. A. C. Lane, of the State Geological Survey of Michigan:

On the evening of November 26th, 1890, at Houghton, Mich., a spot of light was seen on the under surface of a cloud layer, due to a vertical beam of light from a smelting furnace about a mile away. The light was tolerably sharp below and gradually faded out above. The angular altitude of the illuminated spot was measured with a clinometer, and the distance to the furnace was taken from a large scale map. The height of the cloud was then easily found to be from 2,700 to 3,500 feet. At another time, when no angular measures could be conveniently made, two illuminated spots were seen, indicating a double layer of cloud.

This suggests an interesting line of observation for some persevering meteorologist living near a furnace. Observations of this kind patiently continued for a year or more would undoubtedly "throw light" on matters that are now somewhat in the dark. W. M. D.

COMPARISON OF NORMAL BAROMETERS.—In a recent number (July) of the *Met. Zeitschrift*, Dr. Köppen makes use of the comparisons of Drs. Waldo,* Sundell, Brounow, and others, to obtain the differences between the standard barometers of the different weather services. Using the best treatment which the published results permit, he finds that the barometers at Vienna, Paris, Hamburg, and Utrecht (new) form a group below an average normal with differences of —0.03, —0.05, —0.04, —0.02 mm., respectively, while Kew, three Scandinavian, and the

* See this JOURNAL, V. 105-114.

Prussian institute make a group above this normal with differences of +0.08, +0.10, +0.11, +0.06 and +0.08 mm. Between these, and consequently close to the average normal, are the barometers at St. Petersburg, Rome, Munich, Upsala and Dorpat. These variations are so small as to hardly justify a change in the correction to any of the barometers involved. Dr. Köppen praises the care and pains taken in the comparisons above mentioned, and thinks that the variations between the results of different observers is largely due to varying capillary action. He does not give the correction for the Washington and Toronto standards, as the comparisons were due to a single observer, but it appears from Dr. Waldo's observations that they are between 0.1 and 0.2 mm. below the provisional average standard mentioned.

ASCENDING CURRENTS OF AIR.—On this subject there are two interesting reports of the aeronauts who ascended on August 25th, 1889, at Brussels to go to Diest. During the journey, a storm arose in eastern Brabant and the notes that were made on it from the balloons "Industrie" and "Espérance" are thoroughly in accord with the prevailing views on vertical air currents. Thus from the first they reported: "It is 20 minutes before 6. We are running before the storm, as the country beneath us is too wooded to afford us a good landing.——

"We find ourselves soon under a sort of spherical canopy; clouds ascend and descend while they whirl about us; bits of tissue paper when released describe great circles of which we are the center; the earth disappears from our eyes. Godard hangs to the valve line; the balloon is visibly slenderer; the cloth, loose and wrinkled, snaps in the wind, and,—frightful—we constantly ascend. Swept along by a true ascending *trombe*, we suddenly find ourselves 4,000 feet high.

"At this instant,—it is 8 minutes before 6,—a blinding lightning stroke cracks to our right, rising, since it goes around the balloon and ends at our left, while at the same moment sounds a frightful peal of thunder. This thunder stroke is the sign of release. We ascend no longer and soon the earth re-appears to our sight. The sinking becomes ever plainer; it becomes at last so rapid as to make us giddy."

Here we see that, during a storm, strong ascending currents must prevail from the surface to the clouds, and that they must end at the elevation of the storm cloud, where they are broken

by the exhaustion of their energy. This latter observation is supported by guide of the balloon "Espérance." He reports: "I threw out 60 kilos. of ballast; I ascend again now with a force of about 35 kilos., but when we reach the height of the clouds, the ascent suddenly ceases."—*Naturw. Wochensch.*

CLIMATE OF THE STIKINE RIVER DISTRICT.—The Stikine River has its mouth on the Alaskan coast in Lat. 56½°, about opposite the southern end of the island on which Sitka is situated. It traverses the coast range of mountains and yet its gradient is so uniform that it can be ascended by small steamers to Glenora, 126 miles from its mouth, and under favorable circumstances to Telegraph creek, 12 miles further on. Dr. Geo. M. Dawson gives, in the annual report of the Canadian Survey for 1887-88 an interesting account of the reconnaisance of this country, and from his account we draw the following notes on the climate.

The traverse of the coast range by this river from its mouth to Telegraph creek affords an excellent illustration of the difference between coast and inland climates, a difference which is illustrated along almost the entire Pacific coast of America. It is especially remarkable here because the latitude is so high. The annual precipitation at Wrangell, near the mouth of the river is over sixty inches, while at more exposed points on the coast it reaches 100 inches. At Telegraph creek, on the inland side of the mountains the precipitation is so small that it is necessary to irrigate cultivable land. The contrast of the climate is still further increased by the general cloudiness and high relative humidity on the coast with exactly opposite conditions inland at a distance of not more than eighty miles in a straight line. The coast climate is much more temperate than that of the interior which even at Telegraph creek becomes one of extremes. The total precipitation is probably greater at the culminating part of the coast range than on the coast, and, as a large part of this is snow, it accounts for the large accumulations of snow which last into the summer and the glaciers which are found there. Miners give a snow depth of eight or ten feet among the mountains on the lower Stikine. Higher up at Telegraph creek and on the Tahlton river it seldom exceeds eighteen inches, and horses and mules are able to care for themselves a large part of the winter. The great depth of snow retards the spring on the lower river and thus

enlarge the glacier. On passing up the river on the 19th of May Dr. Dawson found the snow much lower on the western than on the eastern side of the mountains, and the vegetation was decidedly further advanced on the inland side.

Decided differences of climate were visible in much narrower spaces. Thus Glenora, twelve miles from Telegraph creek is said to experience much greater cold in winter and the snowfall is three and one-half feet, or more than twice as great. Less snow falls at Tahlton than elsewhere, the amount increasing to the eastward as well as to the westward of this place.

Agriculture at Glenora and vicinity has been confined to the raising of small quantities of vegetables, barley and fodder. Excellent potatoes are raised and escape serious injury by frost. Experiment has proven that wheat and oats can ripen and that the ordinary garden vegetables can be produced. This is a remarkable record for the 58th degree of latitude. There is considerable tillable land there.

The Stikine usually opens for navigation between the 20th of April and the first of May. Ice and sludge begins to run in the river in November. The highest water is early in summer, generally in June.

VARIATIONS OF LEVEL OF LAKES CHAMPLAIN AND ONTARIO.—In the report for 1887 (printed in 1889) of the U. S. Coast and Geodetic Survey, Assistant C. A. Schott gives a preliminary report on the fluctuations of level of Lake Champlain, and compares them with those of Lake Ontario. The Lake Champlain series is of 12 years (1871–1882), and was taken, under the direction of the U. S. Engineers, at Fort Montgomery, near the northern extremity of the lake. The Lake Ontario series was taken by the same service, at Charlotte harbor, as a representative station, for the 23 years from 1859 to 1881. The mean fluctuations about the average level appears in the following table, in feet and hundredths, with meteorological elements for comparison. The rainfalls are in percentages of what it would be if it were distributed equally through the months of the year. That for Western New York is the mean deduced from 27 stations from Mr. Schott's discussion of the Smithsonian observations. That at Burlington is from the Signal Service records for the 11 years, 1872 to 1882. To reduce to approximate inches multiply the first column by three, the second by 2.5.

In the first two columns the *minus* sign means below the mean height, the *plus* sign, above.

TABLE I.

Months.	L. Ontario.	L. Champ.	Rainfall in West. N. Y.	Rainfall at Burlington.	$\frac{S}{N}$
January	−0.57	−0.33	0.78	0.82	1.32
February	−0.61	−0.57	0.69	0.35	0.99
March	−0.37	+0.30	0.79	0.66	0.91
April	+0.21	+1.82	0.86	0.72	0.64
May	+0.68	+2.18	1.14	0.95	1.16
June	+0.82	+0.91	1.29	1.17	1.35
July	+0.73	−0.15	1.28	1.63	1.70
August	+0.46	−0.62	1.09	1.48	1.50
September	+0.07	−0.96	1.07	1.40	1.41
October	−0.30	−1.28	1.17	1.35	1.24
November	−0.58	−0.87	0.97	0.85	1.13
December	−0.59	−0.43	0.87	0.62	1.16

The level of Lake Ontario has a smooth mean annual fluctuation, as is to be expected from so many years of observation. The minimum is in February, and the maximum height in June. A comparison with the rainfall percentages, in the third column, shows that the lake-fluctuations run very consistently with the latter.

The mean fluctuations of the surface of Lake Champlain are not so smooth, as is to be expected both from the shorter series of observations and the smaller size of the lake basin. There is, however, a minimum in February corresponding to the smallest rainfall. The maximum is, however, in May, while the maximum rainfall at Burlington is in July. The rainfall at a single station is so essentially local that no safe conclusions can be drawn from it for such a delicate question as the fluctuations of a large lake near it.

The most remarkable feature of the Lake Champlain level is that the principal minimum falls in October. The level of the lake has been at that time, on the average, over 15 inches below its mean position. This is not dependent on the rainfall. To test its relation to the winds, I have put column five in the table. Winds tend to heap up the waters of a lake at the leeward end. I have therefore taken out from the annual reports of the Chief Signal Officer, for the ten years, October, 1872, to September, 1882, the number of times the wind has blown at Burlington from the NE, N, or NW, which I have called N, and also from the SE, S and SW, which I have called S. The table gives

$S \div N$, or the ratio of the south to the north winds during this period. If the winds have a marked effect on the surface of the lake then the larger this ratio of $S \div N$ the higher should be the *plus* fluctuation. On the average the south winds have been more common at Burlington in the ratio of 1.20 nearly, or 6 to 5. In October, as it happens we have just about the average distribution of winds while the surface is at its minimum. The October minimum on Lake Champlain remains, therefore, unexplained. It would possibly change its character with a longer series of observations.

The average fluctuation from year to year is of interest, and is given in the following table, the values being, as before, in feet.

TABLE II.

Year.	Lake Ontario.	Year.	Lake Ontario.	Lake Champlain.
1859	+0.91	1871	−0.16	−0.05
1860	+0.16	1872	−1.69	+0.73
1861	+0.94	1873	−0.62	+0.39
1862	+0.93	1874	+0.13	+0.70
1863	+0.53	1875	−1.16	−0.29
1864	+0.35	1876	+0.70	+0.18
1865	+0.09	1877	−0.49	−0.55
1866	−0.25	1878	+0.11	+0.10
1867	+0.70	1879	−0.24	+0.03
1868	−0.72	1880	−0.64	−0.58
1869	+0.13	1881	−1.01	−0.61
1870	+1.21	1882	—....	−0.08

The series are not long enough to give definite indications of secular change. It is of interest, however, to note that the surfaces of the two lakes do not change together. At the beginning of the double series Lake Ontario is at its minimum, while Lake Champlain is at its maximum. Towards the end they both fall together.

The highest stage of water observed on Lake Champlain was on May 18, 1876, when the surface was 5.21 feet above the general average. The lowest was on October 12, 1880, when the surface was 2.78 feet below. The absolute range observed at Fort Montgomery is 7.99 for about 8 feet.

The height of the average lake level above mean sea level is 97.17 feet with an uncertainty of ± 0.3 feet. The greatest depth observed below the average level is 402 feet, so that this lake extends over 300 feet below the level of the Atlantic Ocean.

THE CLOUD-ATLAS,* which we announced, Vol. VI, pp. 383-4, has at last appeared, and is well worth possessing on the part of all interested in the subject. It is intended for meteorologists and contains therefore typical rather than beautiful forms of clouds, but these include so many of the latter that it will prove of interest to a wider clientage. The atlas consists of ten quarto chromo-lithographic plates, representing the cirrus, cirro-stratus, cirro-cumulus, cumulo-cirrus, strato-cirrus, strato-cumulus, nimbus, cumulus, cumulo-nimbus and stratus. These are copies of colored paintings, carefully selected from a much larger number. They are well executed, and the care taken in getting the approval of a large number of meteorologists as to their identification gives assurance that represent the typical forms of the clouds in question. These are supplemented by twelve photographs on two sheets which show how these clouds come out by photography, and particularly how different they appear with different kinds of photographic plates.

As this is the first publication of a complete series of clouds in colors, and as they have been made under the direction of especially competent meteorologists, it is probably safe to predict that they will form the basis on which cloud-forms will hereafter be named. Such being the case, no meteorological station can afford to be without them.

NOTES ON THE CLIMATE OF ARIZONA.†—There are two rainy seasons on the San Francisco mountain plateau; one in summer; usually in July or August, the other in midwinter. The summer rainy season is characterized by daily thunder-showers. As a rule, several such showers occur each day, and not infrequently several may be seen at the same time from any of the volcanic cones. The area covered by each is small, its diameter rarely exceeding a half, or even a quarter of a mile; and its duration is brief, though the rain-fall may be considerable. The accompanying thunder is often terrific, and the lightning vivid and destructive. Tall pines are shattered on every hand, and cattle are frequently killed; three were killed by one stroke near our camp about the middle of August, 1889. The showers almost always take place in the day-time, and are most common

*Cloud-Atlas, by Dr. H. H. Hildebrandsson, Dr. W. Köppen, and Dr. G. Neumayer; 10 plates, 12 photographs, and text in four languages, Hamburg, 1890.

†Abstracted from *North American Fauna*, Number 3, by Dr. D. Hart Merriam, of the Department of Agriculture.

at midday and in the early afternoon. In fact, it is a common saying in this region that it never rains at night. Two partial exceptions to this rule occurred during our stay in the summer of 1889; one in which an unusually severe and protracted rain lasted from about three o'clock in the afternoon until nine or ten in the evening; the other, a light shower, which actually took place in the night. . . The greatest precipitation occurs on San Francisco mountain, as would be expected from its great altitude. The summit of the mountain (12,794 feet) is so cold that it is occasionally whitened with snow while rain falls at its base; and hail storms are frequent both on the mountain itself and throughout the plateau region, many sudden storms taking this form. . . .

While following the course of the Tenibito Wash across the Painted Desert, we saw a heavy rain storm raging over the high mesas to the north and east during the entire afternoon of August 14, though not a cloud came between us and the parching sun. Before dark a furious wind—the vehicle of a sand-blast—swept down the wash between the rows of cliffs that mark its course, abating as the night came on. About ten o'clock we were startled by a loud roaring in the north, which at first gave the impression that a severe storm was advancing upon us, but not a cloud could be seen, and the stars were shining brightly in every direction. The roaring increased and came nearer until it was evident that something was coming down the bed of the wash; and in a moment a great wave of thick mud rushed by with a tremendous roar, accompanied by a fetid stench. The first wave was about five feet high, but it soon rose to eight feet, where it remained for an hour, and then slowly subsided.

The Alpine or uppermost of the seven floral zones of San Francisco mountain afforded a number of species of Arctic plants. Nine of the species which grow on the bleak and storm-beaten summit of the mountain were also brought back from Lady Franklin Bay in the polar regions by General Greely. . .

The Grand Canon of the Colorado at the point visited is about fifteen miles wide at the top and six thousand feet deep. It is intersected by gulches and side-canons of gigantic dimensions. It has ledges, terraces and mesas, barren crags and grassy slopes, lofty mountains and deep valleys, cool hillsides clad in forests of balsam firs, and hot bottoms filled with sub-

tropical thickets. It has arid stretches of sand bearing a scattered growth of cactus and yucca, and marshes and springs that never become dry and are hidden by the verdure of a multitude of plants requiring a moisture-laden atmosphere for their existence. Its animal life is as sharply varied and as strongly contrasted. In descending from the plateau level to the bottom of the canon, a succession of temperature zones is encountered equivalent to those stretching from the coniferous forests of northern Canada to the cactus plains of Mexico. These zones result from the combined effect of altitude and slope exposure, the effects of the latter being here manifested in an unusual degree. . . The complex and interacting effects of radiation and refraction, of aridity and humidity, of marked differences of temperature at places of equal altitude on opposite sides of the canon, of every possible angle of slope exposure, of exposure to, and protection from wind and storms, produce a diversity of climatic conditions the effect of which on the vegetable and animal life in the canon has been to bring into close proximity species characteristic of widely separated regions, and to crowd the several life zones into narrow parallel bands along the sides of the canon—bands which expand and contract in conforming to the ever-changing surface.

COLD WAVES.—A cold wave is defined by the Signal Service as a fall in temperature, within twenty-four hours, of twenty degrees or more, by which the air temperature is reduced to forty degrees or lower. Practically, a fall of fifteen degrees, reducing the temperature to forty-five, is considered a verification of a cold wave prediction. The prediction of cold waves is intrusted by the chief signal officer to Professor T. Russell, whose opportunities for their study make his opinion of great interest. In a report to General Greely,* Mr. Russell takes occasion to discuss these phenomena, not only from the forecaster's point of view, but also from that of their general meteorological relations.

As to their prediction, he finds that failures are too frequent, and more frequent in the northwest than elsewhere. The latter is to be expected as it is in the northwest that they most frequently originate, or come first into view. The general result can be stated as follows: When a cold wave warning is given, the chances are six to ten that a cold wave will prevail. In the

*Annual Report of the Chief Signal Officer, 1889. Pp. 145-155.

case of severe cold waves the chance is only one in eight that they will escape prediction, and east of the Mississippi river this chance is reduced to one in seventeen.

Mr. Russell makes a classification of cold waves which affords interesting suggestions as to their origin and nature. He finds that these are of three kinds, which, arranged in the order of their severity are:

1. Those following on areas of low barometer, properly speaking, the rear quadrants of the cyclone, usually west or northwest of the center of low pressure. There is generally a fall of twelve or fourteen degrees in temperature as this part of the cyclone passes over. In autumn or winter this may amount to twenty degrees or more, especially if the low area is of great extent. These cold waves are mild, last five or six hours, and are due to the actual motion of the cold air over warmer areas. The fall of temperature due to this form becomes less as the wave advances eastward. Their rate of advance is that of the low area.

These cold waves may appear anywhere. They generally come from the west and northwest of Lake Superior, and move first southwest to the lower lakes, then northeast to the Gulf of St. Lawrence. Sometimes they appear first in Colorado, when they move eastward; more rarely in Texas or over the Gulf, when they advance east of north or northeast; still more rarely on the Atlantic coast off Florida, whence they travel up the coast or slightly inland. The last are rarely severe enough to be called cold waves.

2. Those with areas of high barometer. These are more severe, and appear usually in Montana, the Dakotas, or to the north of these states. There need necessarily be no accompanying area of low pressure. Their advance is comparatively slow, averaging about three hundred miles per day. There is no actual advancing motion of the air except at the extreme front of the cold wave. They are often of great extent and spread southeasterly, or more nearly easterly, with a vague, uncertain motion. The fall of temperature increases with their appearance eastward. Of these two varieties can be distinguished:

a. Those in which the rise in pressure precedes the fall in temperature. They admit of successful prediction in the Northwest. They are relatively mild and do not advance far. They are probably the ends of severer cold waves in the high Northwest.

b. Those in which the rise in pressure and fall in temperature are simultaneous. These occur over large areas, and do not generally admit of successful prediction.

3. Those occurring between areas of high pressure and extensive and well-marked areas of low pressure. This is the severest form. The advance is very rapid, sometimes 800 miles per day. The area covered is also very large. The area over which the fall of temperature is twenty degrees or more may be half a million square miles, and that with a fall of ten degrees or more, may be three times as great. This form is infrequent, is due to the actual progress of cold air over warmer territories, and is accompanied by high west and northwest winds. The fall of the temperature usually diminishes with advance to the eastward.

These cold waves are especially prolonged and severe when the area of low pressure is elongated in a southwest and northeast direction. It is probably to the last form that the name *blizzard* properly belongs.

Mr. Russell advances the view that the origin of the cold wave is to be found in the commingling of the cold upper with the warm lower air which may take place in the turbulent rear of a cyclone or elsewhere. The result is that the temperature is approximately uniform in the strata in which the mixing occurs, and this means a fall of temperature in tne warmest stratum, or that in contact with the soil. While this may play some part in the phenomenon, it seems to us that the classification given above, and due to Mr. Russell, affords abundant explanation of cold waves without overstepping the accepted theories. The cold waves of the first and third classes are cyclonic and are due to the cold air drawn in from higher latitudes. The waves of the second class are anti-cyclonic and the cold is due to the settling of cold air from above. While there must be much commingling of air in the first and third classes, there appears to be little in the second. However, the opinions of so earnest and an industrious observer as Mr. Russell, are deserving of respectful consideration. It is to be hoped that he will find some opportunity to explain and prove them at greater length.

PUBLICATIONS RECEIVED.

[Our correspondents will kindly take acknowledgment in this list as an acknowledgment of their courtesy in sending us the publications mentioned. In so far as we can find space the publications mentioned here wil be noticed more at length in other parts of the JOURNAL.—EDITORS].

"Nebraska Weather Service," August, 1890. Octavo, four pages.

"Missouri Weather Service Bulletin." August, 1890. Octavo, four pages.

"Report of the Alabama Weather Service," August, 1890. Octavo, four pages.

"Report of the Alabama Weather Service." July, 1890. Octavo, four pages.

"Ciel et Terre." September 1, 1890. Contains several meterological notes.

R. Osservatorio di Palermo, "Bolletino Meterologico." June, 1890. Double sheet.

"Report of the Ohio Meteorological Bureau," August, 1890, Octavo, ninety pages.

"Reports of the Consuls of the United States." No. 117. June, 1890. Octavo, pages 193 to 384.

McGill College Observatory. "Abstract of Observations." August, 1890. Single sheet.

"State Board of Health Bulletin." Nashville, September 20, 1890. Octavo, sixteen pages.

"Bulletin Forty-seven of the Mississippi Weather Service," August, 1890. Octavo, four pages.

Dominion of Canada, Department of Marine. "Twenty-first Annual Report for the Fiscal Year ended 30th June, 1880." Octavo, ninety-nine pages. Also "Twenty-second Annual Re-

port for the Fiscal Year ended June 30th, 1889," Octavo, one-hundred and twenty pages. Ottawa.

"Uebersicht über die Witterungverhältnisse im Königreich Bayern, während des Juli, 1890." Single sheet.

"Uebersicht über die Witterungsverhältnisse im Königreich Bayern während des August, 1890." Separate sheet.

Meterological Service, Dominion of Canada. "Monthly Weather Review." June, 1890. Large octavo, ten pages.

"Kansas Weather Service." August, 1890. Octavo, seven pages. In the *Report of the State Board of Agriculture.*

"Daily International Charts." July 1 to December 31, 1884. Published by the Signal Service. These charts are very neat in appearance.

"Pilot Chart of the North Atlantic Ocean," October, 1890. Single sheet, containing also details as to the hurricane of August 27, 1890.

Observatorio Meterológico-Magnético Central de Mexico. "Boletin Mensual." November, 1889. Quarto, twenty-seven pages.

"Fact and Theory Papers, The Tornado." H. A. Hazen. New York: N. D. C. Hodges, 1890. Small octavo, one hundred and forty-three pages.

"Ciel et Terre" for September 16, 1890, contains the translation of an article by Mr. Symons on the Oscillations of the Barometer during a storm.

"Missouri Weather Service." September, 1890. Double sheet with rainfall chart. Professor F. E. Nepher, Director Washington University, St. Louis.

"Bollettino Mensuale, publicato per cura dell' Osservatorio Centrale del real Collegio Carlo Alberto in Moncalieri," August, 1890. It contains an article by Fr. Denza on the Anticyclone of

November, 1890, and one by St. Bertelli on the Comparative Study of Artificial and Seismic Vibrations, besides many briefer articles and notes.

"Hurricanes of August 27, 1890." Separate sheet with text and charts. From the *Pilot Chart of the North Atlantic Ocean*, (October, 1890) with additional data.

"Revue generale des sciences, pures et appliquées." Semi-monthly. Paris. The number for August 30th contains an article by M. Faye on artificial whirls.

"Naturwissenschaftliche Wochenschrift," 21 September, 1890, contains an article by Ernest Friedel on the snowstorm in the Tyrol on the 12th and 13th July, 1890.

"The Forces Concerned in the Development of Storms." M. A. Veeder, M. D. Octavo, sixteen pages. Reprint from *Proceedings of the Rochester Academy of Science.*

"Public Health in Minnesota." Official publication of the State Board of Health. September, 1890. Vol. IV, No. VII. Octavo, sixteen pages. Address, Red Wing, Minn.

"The Origin of Polar Motion; a New Theory in Which Polar Motion is Proven to be the Repulsive Power of Molecule." M. Myerovitch. Chicago, 1890. Octavo, thirty-two pages.

"Popular Science Monthly," October, contains an article by Dr. Hart on "Invisible Assailants of Health," and a translation of General Tcheng Ki Tong's article on "Irrigation in China."

"Report of the New York Meteorological Bureau," October, 1889, November, 1889, and July, 1890. Each, quarto, eight pages and maps. Professor E. A. Fuertes, of Cornell University, is director.

"Resultate der forstlich-meterologischer Beobachtungen, insbesondere in den Jahren, 1885-1887." 1. Thiel, Untersuchungen über die Temperatur und die Feuchtigkeit der Luft, unter, in und über den Baumkronen der Waldes, sowie im Freilande. By Dr. Joseph Ritter von Lorenz-Liberman, Vienna,

1890. Quarto, ninety-seven pages and many diagrams. *Mittheilungen vom forstlichen Versuchswesen in Oesterreich Heft* 12.

"Bulletin of the New England Meterological Society, in Co-operation with the Astronomical Observatory of Harvard College and the U. S. Signal Service." August, 1890. Large octavo, eight pages.

"Report of the Chief of the Forestry Division, Department of Agriculture," 1889. B. E. Fernow, Chief of Division. Octavo. 58 pages. Reprinted from the *Annual Report of the Department of Agriculture.*

"Michigan Crop Report, No. 107, September 1, 1890, and Forty-third Monthly Report of the Michigan Weather Service, August, 1890." Published by the Secretary of State. Octavo, twenty-five pages, three charts.

"The Climatic Causation of Consumption, with Tables and Diagrams Representing the same." By Henry B. Baker, M. D. Large octavo, forty pages. Reprinted from the *Journal of the American Medical Association,* 1890.

"On Barometric Oscillations During Thunderstorms, and on the Brontometer, an Instrument Designed to Facilitate Their Study." G. J. Symons, F. R. S. Octavo, ten pages. From the Proceedings of the Royal Society.

"Das Wetter" for September 1890 contains a continuation of Dr. Lang's article on Weather-forecasting, an article on Trombes on the Hoogly and another on the Chinook and Blizzard by Dr. P. Andries, and many briefer articles and notes.

"Meteorologische Zeitschrift" for September, 1890, contains: W. von Siemens, General Wind-System of the Earth (seven pages); Dr. Hann, Temperature in Cyclones and Anticyclones (sixteen pages); Mr. R. H. Scott, a translation of his article on variability of temperature on the British Islands from the *Proceedings of the Royal Society* (three pages) and many briefer articles and notes.

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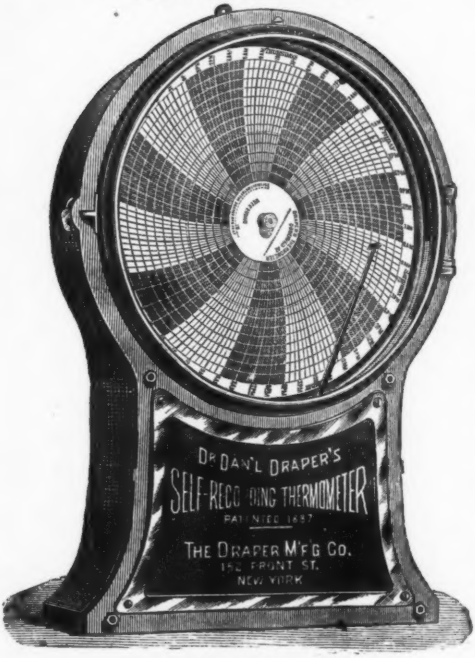

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